The Use of Red Green Blue (RGB) Air Mass Imagery to Investigate the Role of Stratospheric Air in a Non-Convective Wind Event

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The Problem

- Non-convective winds cause as many fatalities as thunderstorm straight-line winds
- Tropopause folds and the sting jet are responsible for non-convective winds, however the sting jet is only known to occur in North Atlantic Shapiro-Keyser cyclones
- The global distribution of sting jet cyclones is unknown and questions remain whether cyclones that impact the U.S. develop sting jet features
- Analyses of the new RGB Air Mass imagery, show the utility of future GOES-R products in forecasting non-convective wind events

Background

- Stratospheric intrusions and tropopause folds can be identified by high-potential vorticity, warm, dry, ozone-rich air

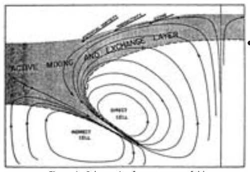

Figure 1. Schematic of a tropopause fold (Danielson 1968)

- 1.5-2 PVU represents the dynamic tropopause
- Abrupt folding of the tropopause is associated with a PV anomaly

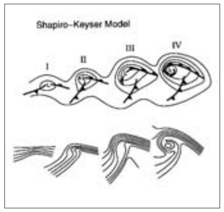

Figure 2. Conceptual model of Shapiro-Keyser cyclones. Upper: sea level pressure and fronts Lower: temperature (Shapiro and Keyser 1990)

- The sting jet is a mesoscale phenomena in Shapiro-Keyser cyclones where strong winds originate and descend from the tip of the comma head (see Figs. 10 and 12 inset)
- The RGB Air Mass product is able to identify temperature and moisture characteristics surrounding synoptic features
- The product is created by combining multiple channels and channel differences

Color	Band/Band Diff.	Physically Relates to…	Little contribution indicates…	Large contribution indicates…
Red	6.7-7.3	Vertical water vapor difference	Moist upper levels	Dry upper levels
Green	9.7-10.7	Estimate of tropopause height based on ozone	Low tropopause, more ozone, polar air mass	High tropopause, less ozone, tropical air mass
Blue	6.7	Water vapor ~500-200 mb layer	Dry upper levels	Moist upper levels

Table 1. RGB Air Mass product recipe based off EUMETSAT RGB guidelines

- **Red/Orange** → Vorticity/Jet Streak, dry air pulled down on anticyclonic side of the jet
- **Olive** → Warm, moist air and mid-level clouds
- **Green/Blue** → warm moist upper level air

Event Analysis

Figure 3. 0000 UTC 09 February 2013
HPC Surface Analysis

- A low pressure system over the Ohio Valley merged with a system off the East Coast by 0000 UTC 09 February 2013
- At 0000 UTC the low pressure system developed a bent-back feature analyzed as an occluded front (compare to III and IV in Fig. 2)

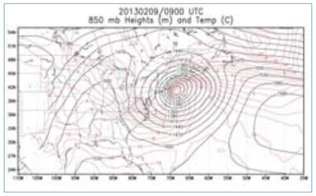

Figure 4. 0900 UTC 09 February 2013
MERRA 850 hPa Analysis

The 850 hPa temperature field resembled the Shapiro-Keyser model with a stronger gradient associated with the warm front and fronts appear perpendicular. The features were sharply defined by 0900 UTC 09 February (Compare to III in Fig. 2)

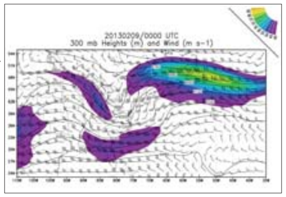

Figure 5. 0000 UTC 09 February 2013
MERRA 300 hPa Analysis

- Stronger 300 hPa winds downstream established confluent flow and Shapiro-Keyser cyclone characteristics were able to develop

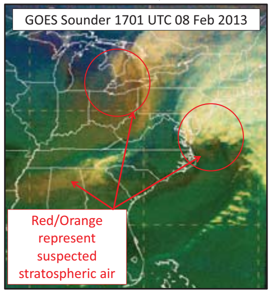

Figure 6. 1701 UTC 08 February 2013
CIRA/SPoRT GOES Sounder proxy RGB Air Mass image

- Two distinct storms the previous day, circled regions on Fig. 6 represent possible stratospheric air
- SPoRT AIRS Ozone Anomaly (Fig. 7) shows some high ozone values are classified as stratospheric air
- Anomalies were calculated as a percent of normal using AIRS Total Column Ozone and a satellite derived stratospheric ozone climatology
- Recent literature classifies stratospheric air as ozone values ≥125% of normal

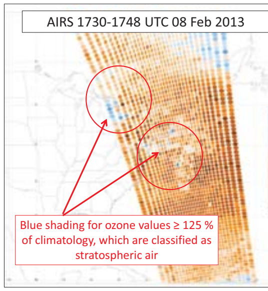

Figure 7. 1730-1748 UTC 08 February 2013
SPoRT AIRS Ozone Anomaly (% of Climatology, values ≥ 125% and shaded blue represent stratospheric air)

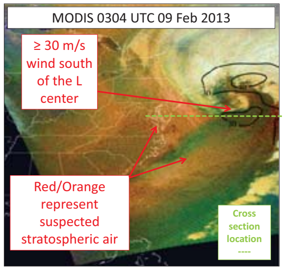

Figure 8. 0304 UTC 09 February 2013
SPoRT MODIS RGB Air Mass image. 13-km RAP 925 wind (m/s, black contours)

- By 0300 UTC 09 February a distinct sting-jet like wind maximum developed south of the low center (Fig.8)
- The region of stratospheric air in Fig. 8 is confirmed by overlaying model PV (Fig. 9)

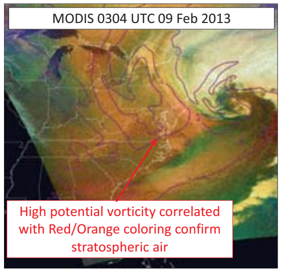

Figure 9. 0304 UTC 09 February 2013
SPoRT MODIS RGB Air Mass image. 13-km RAP 400-200 layer hPa PV (PVU, purple contours)

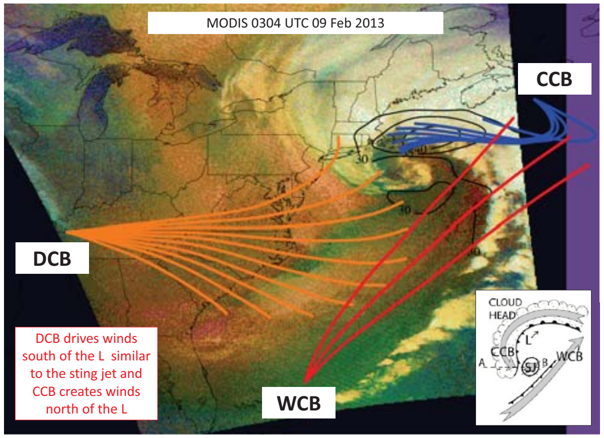

Figure 10. 0304 UTC 09 February 2013
SPoRT MODIS RGB Air Mass image and 13-km RAP wind (m/s, black contours). HYSPLIT 24-hour forward trajectories starting at 0300 UTC 08 February 2013. Dry conveyor belt (DCB) in orange, cold conveyor belt (CCB) in blue, and warm conveyor belt (WCB) in red. Inset here and Fig. 12 is a conceptual model of sting jet (SJ) in stage II of Shapiro-Keyser cyclones and relationship to WCB, CCB, and DCB (dry intrusion), plan view inset here and vertical cross section inset in Fig. 12. [@ Wiley 2005, (Clark et al. 2005)]

- Positioning of the wind maximum relative to the conveyor belts in Fig. 10 is similar to the inset conceptual model
- As the DCB traversed, upper-level dry air descended and contributed to the high near-surface winds. CCB winds were distinct from the sting-jet like wind maximum
- Cross sections (Figs. 11 and 12) show the connection between the tropopause fold, descent of dry air, and high near-surface winds

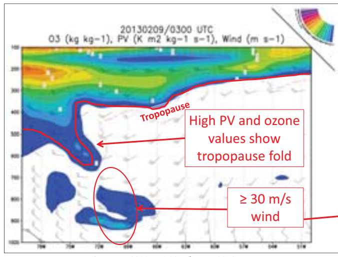

Figure 11. 0300 UTC 09 February 2013
MERRA cross section across 38° N latitude of ozone (kg/kg, red dashed), potential vorticity (Km²/kg/s, shaded), wind (m/s, barbs)

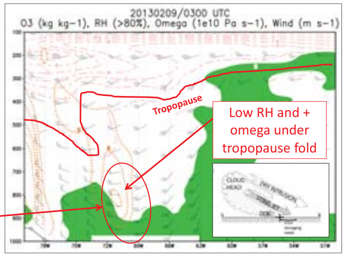

Figure 12. 0300 UTC 09 February 2013
MERRA cross section across 38° N latitude of ozone (kg/kg, red dashed), omega (1e10 Pa/s, orange dotted), wind (m/s, barbs), relative humidity (>80% shaded green)

- 13-km RAP analysis of frontogenesis (Fig. 13), shows features similar to the sting jet conceptual model
- Rapid weakening of the bent-back front creates a region of frontolysis
- Maximum winds are downstream of the frontolysis (see Fig.13 inset)

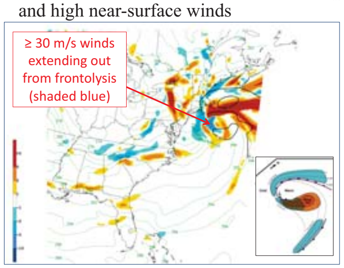

Figure 13. 0300 UTC 09 February 2013
13-km RAP 925 mb wind (m/s, black contours)
frontogenesis (K/100 km/3 hr, shaded) and theta (K, green dotted). Inset is the Sting jet conceptual model (Schultz and Sienkiewicz 2013)

Summary

- AIRS ozone and model PV analysis confirm the stratospheric air in RGB Air Mass imagery
- Trajectories confirm winds south of the low were distinct from CCB driven winds
- Cross sections connect the tropopause fold, downward motion, and high near-surface winds
- Comparison to conceptual models show Shapiro-Keyser features and sting jet characteristics were observed in a storm that impacted the U.S. East Coast
- RGB Air Mass imagery can be used to identify stratospheric air and regions susceptible to tropopause folding and attendant non-convective winds